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ABSTRACT

The purpose of this study was to develop, implement, and evaluate an audiotape and accompanying handouts on hemodynamics as a supplemental teaching aid in the Health Science Learning Center of New York City Technical College. It was hypothesized that there would be a significant difference between the mean examination grade on hemodynamics of students exposed to the teaching aid and those not exposed to the teaching aid. The control group consisted of 20 students from one section of the course who were exposed to classroom instruction only, and the experimental group was made up of 20 students from another section who were exposed to classroom instruction and the teaching aid. Findings confirmed the hypothesis and indicated the effectiveness of the teaching aid. As a result of the study it was recommended that the teaching aid be implemented permanently and that more studies be conducted to ascertain further validity of the instrument. Development of similar teaching aids on other topics of interest and seeking funding for development of additional teaching aids were also recommended. The script of the audiotape, the accompanying handouts, and statistical data from the evaluation are appended. (30 references) (Author/MES)

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DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF AN AUDIOTAPE AND ACCOMPANYING VISUALS IN HEMODYNAMICS AS A SUPPLEMENTARY TEACHING AID FOR HUMAN ANATOMY AND PHYSIOLOGY

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Abstract

DEVELOPMENT, IMPLEMENTATION AND EVALUATION OF AN AUDIOTAPE AND ACCOMPANYING VISUALS IN HEMODYNAMICS AS A SUPPLEMENTARY TEACHING AID FOR HUMAN ANATOMY AND PHYSIOLOGY

Ranjani H. Selvadurai

Difficulties associated with the comprehension of Hemodynamics in the Human Anatomy and Physiology course at NYCTC, had been the consensus of the course committee and a large sector of the student clientele for some time. This had been attributed to the physical and mathematical principles involved in the topic. In addition the material on the topic in the text used was found to be inadequate.

The purpose of the study was to develop, implement and evaluate an audiotape and accompanying handouts on the topic as a supplementary teaching aid in the Health Science Learning Center of New York City Technical College. Twenty students from one section of the course who were exposed to classroom instruction only, were used as the Control Group. Twenty students from another section of the same target group, who were exposed to classroom instruction and the teaching aid were used as the Experimental Group in the study. An independent t test was conducted in the study to determine whether there was a significant difference

between the mean examination grade on Hemodynamics of students who were exposed to the teaching aid and the mean examination grade of students who were not exposed to the teaching aid. The Null Hypothesis was stated as $H_0: u_1 = u_2$. and the Alternate Hypothesis wa stated as $H_a: u_1 \neq u_2$. The critical t value for a two-tailed test was established at a significance level of .05. The calculated t value was compared to the critical t value to determine whether or not the Null Hypothesis was to be rejected.

The results of the study indicated that the calculated t value was greater than the critical t value at a significance level of .05, thus rejecting the Null Hypothesis. The findings indicated that there was a significant difference between the mean examination grade on Hemodynamics of students exposed to the teaching aid and the mean examination grade on Hemodynamics of students not exposed to the teaching aid. The results further indicated the effectiveness of the teaching aid.

As a result of the study it was recommended that the teaching aid be implemented permanently in the HSLC, and that more studies be conducted to ascertain further validity of the instrument. The development of similar teaching aids on other topics of interest as well as exploring avenues of funding for the development of additional teaching aids were recommended.

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INTRODUCTION

The practicum involved the development, implementation and evaluation of an audiovisual aid in Hemodynamics as a supplementary teaching aid. The audiotape and the accompanying handouts were designed to be used in the Health Science Learning Center by students enrolled in the Human Anatomy and Physiology course at New York City Technical College. This course is a two semester course designated BY 301.1 and BY 301.2 offered by the Department of Biological Sciences and mandated for students in the curricula of Medical Technology, Nursing, Dental Hygiene and Radiologic Technology. The unit in Hemodynamics is offered in the second semester of the course.

It has been the consensus of the course committee and a large sector of the student clientele who had previously taken the course, that the topic in Hemodynamics is difficult and not easily comprehended. The topic deals with physical principles associated with the flow of blood in the circulatory system in the human. Most students enrolled in the course have a limited knowledge in physics and advanced mathematics. In addition there is an inadequacy of material covered on Hemodynamics in the text

used in the course. The course committee was of opinion that the topic needs reinforcement through teaching aids in the Health Science Learning Center.

The purpose of the study therefore, was to develop, implement and evaluate an audiotape with accompanying hand outs to be utilized as a supplementary teaching aid in the Health Science Learning Center. Five students who had completed the course were randomly selected and interviewed for their input in difficulties pertaining to the topic on Hemodynamics. The script for the audiotape and the hand outs were developed. They were further refined for content, readability and style with the assistance of three faculty members of the course committee. The audiotape was prepared with the assistance of the media services of the school and five copies of the tape and one hundred copies of each of the handouts were made available to the Health Science Learning Center. A formative study of the tape was performed by testing the instrument with five randomly selected students who had previously covered the unit in class.

Therefore, an attempt was made to determine if there was a significant difference between the mean examination grade on Hemodynamics of students exposed to the teaching aid and the mean examination grade on Hemodynamics of students not exposed to the teaching aid.

The Research Hypothesis in the project was stated as " There is a significant difference between the mean examination grade on Hemodynamics of students exposed to the teaching aid and the mean examination grade on Hemodynamics of students not exposed to the teaching aid. " The teaching aid was evaluated for one semester with two sections of students from the same curriculum enrolled in the course. Twenty students (Group I) from section A who were exposed to classroom instruction only, were randomly selected as the Control Group. Twenty students (Group II) from section B who were exposed to classroom instruction of the unit and to the teaching aid were randomly selected as the Experimental Group. Appropriate statistical analysis was applied to the data, and the calculated t value was compared to the critical t value to determine significance or lack of significane in the study.

The findings of the study were presented to the chairperson of the Department of Biological Sciences. The results of the project were also presented to the Human Anatomy and Physiology course committee of the department with recommendations for additional studies to ascertain further validity of the project.

Background and Significance

Instruction has been defined as a set of planned external events which influence the process of learning and promote learning (Gagne, 1974). Traditional attempts as the one best mode of conveying a subject have fallen short of providing a single accepted instructional technique that is most successful in terms of learning outcomes. Many educators have abandoned an eclectic mode of instruction and instead they have attempted to identify contextual factors (e.g. student, instructor, learning objectives, learning and teaching styles and educational environment) and relate them to alternative instructional methods in order to discover the most effective conditions for learning.

Trends in greater accountability, increased heterogeneity of students and new developments in technology have led many educators to propose new methods and techniques for improvement of instruction (Conrad, 1982). The rapidity of technological change has strained the capacity of the training systems to meet the demand for new skills and abilities. In response to these demands a flood of instructional materials is being produced especially by institutions of higher education.

One approach to media utilization that has produced claims for meaningful instructional advantages has been the development of adjunctive audio/pictorial presentations to accompany printed texts (Main et.al., 1977; Cole, 1982). Such approaches are potentially cost effective to the extent that they take advantage of existing materials. Unfortunately, most experimental evaluations of adjunctive media presentations have confounded the effects produced by media with those produced by other factors such as content, repetition or study time.

Records and audiotapes have been used for self-study since World War II mainly in teaching of languages and recently in a growing number of other areas (Grayson, 1982). Although enormous sums are being spent on audiovisual equipment, selection of media has often been found to be not based on evidence of instructional effectiveness. Traditionally, media were selected on the basis of relevent content, practicability, cost and preferences of teachers and institutions. However, most systems models now call for a more explicit rationale for relating media to learner and task characteristics (Briggs, 1982).

A significant use of audiotapes in altering traditional classroom approaches was made by Postlethwait in 1961 when he developed the audio-tutorial method of

instruction. The approach had three major components including study sessions by the usage of audiotapes and other media in self-instructional carrels, general assembly sessions and weekly quiz sessions (Postlethwait, Novak and Murray, 1971). The approach was very successful and has been initiated and adopted in several subject areas at institutions of higher education.

Audio supplements have been found to change the character of informational presentations. The effectiveness of print/pictorial presentations was further found to improve through addition of audio (Sellman, 1972). In addition to reinforcing the informational content, adjunctive media like audiotapes may change the amount of study time required of an individual to complete the instruction. One of the underlying percepts of using audiovisual aids is that of organization and an orderly flow of information (Potter, 1978). Audiovisuals by their very nature provide a framework within which an organized effort in teaching is not only possible but easily managed. Most instruction contains information which is important. However, if this information is not presented effectively the end result may be confused or ill informed students.

Audiotape recorded lessons in place of lectures have been utilized in special education classes at Moorhead State University, Minnesota in a program referred to as

Audio-Assisted Independent Study (AAIS). Central to this program has been the thesis that students can learn from audiotape recordings as well as from live lectures. Using a combination of face to face meetings, audio tapes and other assignments a pattern of instruction can be developed that alleviate problems of off-campus education such as instructional delivery to remote areas (Thorman, 1977; McMeen, 1984). The use of audiotapes in independent study courses are manyfold. They are:

1. The student may learn at a convenient time and place of choice.

2. Students living in more remote areas where university courses would not be offered on a regular basis, have the opportunity to pursue their educational goals. Their accessibility to educational offerings is provided.

3. In studying via audio cassettes, students have the option of reviewing lecture content whenever it is convenient.

4. With this form of individualized instruction, students may proceed at their own rates of learning.

The premise that the addition of visual presentations improved the effectiveness of verbal instruction has been well documented. Peak (1974) reported that the addition of pictures aided comprehension. Rasco, Tennyson and Boutwell (1975) found visual additions facilitated comprehension of mathematical concepts. Dwyer (1968), contended that supplementary verbal instruction with

pictures may draw attention to particular points of information as they may emphasize functional or structural relationships that were hidden in the verbal content.

A further point of interest noted by studies of media comparisons is the interaction between the effects of media and the verbal ability of students. Individual differences towards verbal ability in students have indicated that those with high and low verbal abilities respond differently to various media combinations and instructional strategies (Gropper, 1965; Bush, Gregg and Macbride, 1965).

A great deal of research has been conducted on the effectiveness of the audio-tutorial approach with mixed results. Meta-analysis done by several investigators have conveyed that the audio-tutorial approach had a significant but small overall effect on student achievement in college courses. The studies further indicated that this approach had no significant effect on student course evaluations or course completions (Kulik et. al., 1979; Kulik, 1982). There has been a reluctance among educators to use audio-tapes extensively as an instructional tool. This reluctance may in part be due to the lack of empirical data demonstrating the efficacy of instruction with the use of audiotapes (Wasson et. al., 1975).

Incorporation of audiovisuals in teaching have a learning impact. To direct and control this impact is a main concern of any instructor interested in using audiovisuals as a tool in education. The use of audiovisuals cannot be haphazard if student learning is to result from them. Technological developments are resulting in new hardware devices that are providing a plethora of opportunities for improved learning by people at all age levels both in school and non-traditional settings. The problems that confront educators are, to use these technologies in ways that are effective and affordable.

The course in Human Anatomy and Physiology is the largest service course offered by the Department of Biological Sciences. Over the last five years the number of sections in this two semester course has drastically increased especially because students from the nursing curriculum of two hospitals in Brooklyn have been granted enrollment in the course. The course is mandated for students enrolled in the curricula of Medical Technology, Nursing, Dental Hygiene and Radiologic Technology of the college.

Throughout the years the course committee has made several revisions of the course to cater to the needs of the varied student clientele of the course. The selection of a suitable text that covers all areas of the course

outline has been a problem for the course committee for a considerable period of time. Hence, attempts have been made by the committee to reinforce the material covered in class and in the text with supplementary teaching aids. It has been the consensus of the course committee and the student population of the course that the topic in Hemodynamics is difficult to comprehend. This unit incorporates several physical principles that calls for a fair knowledge in physics and mathematics. It has been evident that the students enrolled in this course are especially lacking in this requirement. In addition, the material covered in the text on Hemodynamics is considered to be inadequate. Hence, there has been substantial call for supplementary material on the unit. The study was undertaken as an attempt to supplement the information on Hemodynamics, with a teaching aid in the form of an audiotape and accompanying handouts in the Health Science Learning Center.

The study was appropriate for the seminar on Curriculum and Program Planning as development and implementation of audiovisual teaching aids was an integral part of the course. Usage of audiovisuals especially as supplementary teaching aids have been in the vanguard through the influence of audio-tutorial teaching techniques introduced by Postlethwait in the 1960s to date.

PROCEDURES

In an attempt to develop, implement and evaluate an audiotape and accompanying visual aids in Hemodynamics, the following procedures were adopted.

Permission to conduct the study was obtained from the chairperson and the course committee of the Human Anatomy and Physiology course of the Department of Biological Sciences. Further review of literature on Audio-visual aids was accomplished with the assistance of an Eric Search and the libraries of the City of New York.

Five students who had previously completed the course were randomly interviewed. The purpose of these interviews was to obtain their perceptions with reference to content covered and the difficulties encountered by students in comprehending the topic on Hemodynamics. The script for the audiotape and the accompanying handouts were prepared (Appendices A and B) and were examined for content readability and style by a panel of three judges of the course committee. Appropriate modifications were made as specified by the panel of judges. The audiotape was prepared with the assistance of the media services of the college and one hundred accompanying handouts were prepared with the assistance of the Reprographics Department of the

college. A formative study was conducted for testing the teaching aid with five randomly selected students who had previously covered the unit in class.

A request was made to the Department of Biological Sciences for the investigator to teach at least two sections of BY 301.2 from the same curriculum (i.e. Medical Technology, Nursing, Dental Hygiene or Radiologic Technology) for one semester. The Department of Biological Sciences honored the request. The purpose of the request was to utilize two sections of students from the same target group with similar levels of reading, writing and knowledge in Biology.

One section (Section A) of students enrolled in BY 301.2 was subjected only to traditional teaching of the topic in Hemodynamics in the classoom. Two weeks after the topic was covered in class, the students were tested with an examination of twenty five multiple choice questions on the topic. The second section (Section B) of students enrolled in the course was also subjected to traditional classroom instruction of the topic, but was also mandated the usage of the supplementary teaching aid within the next two weeks in the Health Science Learning Center. Instructions were given to the Health Science Learning Center that only students specified from a listing (i.e. students in Section B) were to be permitted to use

the teaching aid at this experimental stage. An attendance check was kept in the Learning Center, of students who utilized the supplementary teaching aid. Students in Section B were also tested after two weeks of coverage of the material in class, with the same examination given to students in Section A with the sequence of the question numbers rearranged. The grade in the unit examination on Hemodynamics was used in the study as the paradigm of measurement of effectiveness of the supplementary teaching aid.

A sample of twenty students was selected at random from Section A and was designated Group I (Control Group) The grades on the examination on Hemodynamics for Group I were tabulated. Attendance of students who utilized the supplementary teaching aid was checked. A sample of twenty students from this category was selected at random to form Group II (Experimental Group). The grades on the examination on Hemodynamics for Group II were tabulated.

The Mean and Standard Deviations of the unit examination grades of Groups I and II were computed. The Null Hypothesis (H_0) was stated as H_0: $u_1 = u_2$ (u_1 = mean examination grade of Group I; u_2= mean examination grade of Group II). The Alternate Hypothesis was stated as H_a: $u_1 \neq u_2$. The level of significance was established at .05. The degrees of freedom were calculated for Group I and

Group II and the critical t value for a two-tailed independent t test was established. The t value was calculated using the appropriate formula. The calculated t value was compared to the critical t value to determine whether or not the Null Hypothesis was to be rejected.

The results of the study were presented to the chairperson and the course committee of the Department of Biological Sciences with recommendations for additional studies to ascertain further validity of the project.

Limitations of the Study

The study was limited to students enrolled in the course from one curriculum. In addition the study was limited to two sections of students enrolled for one semester in the course.

Basic Assumptions

An Assumption of the study was that both groups of students had been exposed to the same subject matter in Biology. Further it was assumed that the two student groups were heterogeneous with respect to age, sex, reading and writing levels, intelligence and motivation. It was also assumed that the average study time given to the topic by both groups of students to be relatively similar.

Definition of Terms

The operational definition of terms in the project were as follows:

BY 301.2	Course code for Human Anatomy and Physiology II.
HSLC	Health Science Learning Center.
Hemodynamics	Study of the physical principles associated with the flow of blood in the circulatory system in the Human.

RESULTS

Table 1 represents the Sample sizes, Means, Standard Deviations and the calculated t value at a significant level of .05.

Table 1

Sample sizes, Means, Standard Deviations and t Value for Groups I and Group II

Group	N	X	S.D.	t
I	20	74.00	9.695	
II	20	77.15	9.634	4.59*

* Significant at .05 level

The Mean for Group I (Control Group) consisting of students who were exposed only to classroom instruction in Hemodynamics was 74.00 with a Standard Deviation of 9.695 for a sample size of 20. The Mean for Group II (Experimental Group) of students who had classroom instruction of the topic and also used the teaching aid on the topic was 77.15. The Standard Deviation for Group II (Experimental Group) was 9.634 for a sample size of 20. The critical t value for 38 degrees of freedom at a significant level of .05 was established at + 1.96. The calculated t value for an independent t test was 4.59.

DISCUSSION, IMPLICATIONS AND RECOMMENDATIONS

The results of the study indicated that the calculated t value was greater than the critical t value at a significance level of .05. Therefore, the Null Hypothesis was rejected indicating that there was a significant difference between the mean examination grade of students exposed to the supplementary teaching aid and the mean examination grade on Hemodynamics of students not exposed to the supplementary teaching aid. The findings confirmed that the mean lecture grade of 77.15 for Group II (Experimental Group) compared to the mean lecture grade of 74.00 of Group I (Control Group) was significantly

different indicating a positive learning effect with the usage of the audiotape on Hemodynamics and the accompanying handouts.

The use of audiotapes and accompanying supplementary visual teaching aids were in the vanguard in 1960s with their introduction as teaching tools by Postletwait. Although more sophisticated modes of instruction have evolved, several educators yet opt the use of audiotapes in instruction. The present findings indicated a significant effect on learning with the use of the teaching aid. This is in congruence with the findings of (Sellman, 1972; Potter, 1978; Peak, 1974; Rasco et. al., 1975; and Dwyer 1968). Sellman (1972) contended that the effectiveness of print pictorial presentations further improved through the addition of audio. Potter (1978), asserted that one of the underlying percepts of using audiovisual aids was the organization and an orderly flow of information fostering easy management of instruction.

Contrary to present findings that indicated a positive effect on learning with audiovisuals, another school of thought had findings to support an opposing view. Meta-analysis on research findings by Kulik et. al. (1979), and Kulik (1982) indicated that the audio-tutorial approach had a significant but small overall effect on student achievement on college courses. Perhaps it could be

argued that in the present study the significant increase in learning of the Experimental Group, may be due to increased study time and repetition with the use of the teaching aid. However, if repetition was the only significant factor, a similar gain could have been obtained by repetitive study of the material that was covered in class.

At least three factors, repetition, selective attention and organization may have contributed to the performance gains of the experimental group in the present study. The relative importance of these factors and their interaction with learning ability are matters that can be determined only through further studies. The present findings suggested that the provision of media supplements will particularly facilitate learning under certain conditions.

The study had some implications for the institution. Continued use of supplementary learning aids especially in the form of audiotapes in the Health Science Learning Center will enhance learning. The audiotape and the visual aids developed in the study were an addendum to the supplementary instructional material in the Health Science Learning Center. Such audiovisual supplements especially aid students in learning topics that are more difficult to comprehend thereby improving their course

grades. In addition, the availability of the audiotape and the accompanying handouts were expected to benefit students who missed the topic in class due to absenteeism. Increased performance in class examinations via the use of the audiotape and the accompanying handouts will increase student retention rate, thus increasing enrollment in the more advanced courses in the following semester. Such a sequence undoubtedly will increase revenue to the college.

As a result of the study the following recommendations were made to the Department of Biological Sciences.

1. The audiotape and the accompanying visual aids developed in the study be implemented on an on-going basis in the Health Science Learning Center.

2. Further evaluation studies be conducted with students from different curricula enrolled in the course to ascertain further validity of the instrument.

3. Encourage the development of supplementary teaching aids on other topics in Anatomy and Physiology, as well in other areas of study that will enhance the learning process.

4. Seek additional funding from the college and through grants from external agencies for development of similar and more sophisticated teaching aids in the Health Science Learning Center.

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APPENDIX A

Script For Audiotape on Hemodynamics

Script For Audiotape on Hemodynamics

Instructions for Students:

Before listening to the audiotape on Hemodynamics please obtain from the main desk of the Health Science Learning Center, the handouts that accompany material covered on the audiotape

Hemodynamics involves the physical laws involved in the flow of blood in the Human body. Before dealing with the main topic of Hemodynamics, definition of some of the terminology pertaining to the topic is important. They are:

Blood Flow	Is the volume of blood flowing through a vessel or a group of vessels in a given time.
Velocity of Blood	Is the distance blood flows in a vessel during a given period of time.
Blood Pressure	Is the force that blood exerts against the walls of the vessel.
Peripheral Resistance	Is a force due to the friction between blood and the walls of the vessel, which impedes blood flow.
Viscosity of Blood	Is a measure of the reluctance of blood to flow. Viscosity depends on the thickness of blood (i.e. on the number of Red blood corpuscles and on Plasma Proteins).

The primary function of the circulatory system is to supply a continuous flow of blood to different tissues. Blood flows from an area of high pressure to an area of low pressure. If the pathway of blood is started for instance from the left ventricle, the following route will be followed:

Left Ventricle ⟶ Aorta ⟶ arteries ⟶ smaller arteries ⟶ arterioles ⟶ capillaries ⟶ venules ⟶ smaller veins ⟶ larger veins ⟶ Vena Cavae ⟶ Right Atrium ⟶ Right Ventricle ⟶ Pulmonary Artery ⟶ Lungs ⟶ Pulmonary Vein ⟶ Left Atrium ⟶ Left Ventricle.

The Heart acts as a pump in the flow of blood. Each contraction of the heart generates a pressure which is proportional to the kinetic energy associated with blood flow. As the blood flows through the closed circulatory system it meets with resistance from the walls of the blood vessels. Blood has laminal flow (i.e. it flows in layers. Refer Diagram I). The outer layers have the greatest resisitance. In a vessel, an infinitely thin layer of blood always remains attached to the blood vessel. If the blood vessels were not elastic, the blood flow will be intermittant (i.e. blood will flow during systoly and there will be no flow during diastoly). However, in the circulatory system blood flows continuously due to the elastic nature of the arterial walls. Systole causes the

elastic walls of the blood vessels to distend. When this happens, potential energy is stored up in the walls of the vessels. When diastole takes place the blood vessels recoil and potential energy is converted to kinetic energy which helps to squeeze the column of blood forwards in a continuous stream.

Prior to studying the physical principles associated with the flow of blood, let us try to understand some of the physical principles associated with the flow of fluids in general.

Effect of Pressure on Flow of Fluids

Please refer Diagram II in the handouts. This illustrates the effect of pressure on flow of fluids. The first cylinder in the diagram has a pressure due to a column of 1 foot of fluid, the second cylinder a pressure due to a column of 2 feet of fluid and the third cylinder a presuure due to a column of 3 feet. The rate of flow in the first cylinder is 1 gallon/minute, in the second cylinder 2 gallons/minute, and in the third cylinder 3 gallons/minute. This illustration therefore indicates that:

Flow $\propto$ Pressure

$F \propto P$

Effect of Length of Vessel on Flow of Fluids

Please refer Diagram III in handout. This diagram illustrates the effect of the length of a vessel on the flow of a fluid. In the diagram the first vessel is 3 inches long, the second vessel is 2 inches long and the third vessel in an inch in length. If the pressure in the three vessels is kept constant (e.g. 100 m.m. of mercury), if the rate of flow in the first vessel is 1 ml/minute, the flow in the second vessel will be 2 ml/minute and in the third vessel the rate of flow will be 3 ml/minute. Diagram III illustrates that the flow of a fluid is inversely proportional to the length of the vessel.

$$\text{Flow} \propto \frac{1}{\text{Length of Vessel}}$$

i.e. $F \propto \frac{1}{L}$

Effect of the Radius of the Vessel on Flow of Fluids

Please refer to Diagram IV of the handout. This diagram illustrates the effect of the radius of a vessel on the flow of a fluid. The first vessel has a radius of 1 mm, the second vessel a radius of 2 mm, and the third vessel a radius of 4 mm. If the pressure in the vessels is kept constant (e.g. 100 mm of Mercury), if the rate of flow in the first vessel is 1 ml/minute, the rate of flow in the

second will be 16 ml/minute and that in the third vessel will be 256 ml/minute. This indicates that as the radius of a vessel doubles, the flow in the vessel increases by the fourth power of the radius (i.e. Flow is directly proportional to the fourth power of the radius.

$$\text{Flow} \propto \text{Radius}^4$$

i.e. $F \propto r^4$

Effect of Viscosity (η) on Flow of a Fluid

Please refer to Diagram V in the handout. This diagram illustrates the effect of Viscosity on the rate of flow of a fluid. The first cylinder has water, the second cylinder has blood plasma and the third cylinder has normal blood. the pressures in all three cylinders are kept constant (e.g. 100 mm of merucury). The first cylinder has a rate of flow of 3 ml/minute, the second cylinder a rate of flow of 2 ml/minute and the third cylinder a rate of flow of 1 ml/minute. Water has the least viscosity, next the plasma and normal blood has the highest viscosity (viscosity is the reluctance to flow of a fluid). This diagram illustrates that the flow of a fluid is inversely proportional to viscosity.

$$\text{Flow} \propto \frac{1}{\text{Viscosity}}$$

i.e. $F \propto \frac{1}{\eta}$

Physical Principles Associated with the Flow of Blood

Please refer Diagrams VI and VII in the handouts. Flow of blood depends on several factors. In Diagram VI, flow of blood from point A to point B is directly proportional to the pressure difference between the two points. Let us indicate the pressure at point A as P_A and the pressure at point B as P_B. Blood flow from point A to point B is directly proportional to $P_A - P_B$.

Blood Flow Pressure difference between point A and point B.

i.e. $F \propto P_A - P_B$

Please refer Diagram VII. We have already indicated that:

$$F \propto P_A - P_B \qquad \text{——————(1)}$$

Also the flow of blood is inversely proportional to Resistance (R).

$$\text{i.e. Flow} \propto \frac{1}{\text{Resistance}}$$

$$F \propto \frac{1}{R} \qquad (2)$$

Combining equations (1) and (2) :

$$F \propto \frac{P_A - P_B}{R} \qquad \text{——————} \quad (3)$$

Resistance however depends on several factors. They are:

1. Length of the blood vessel (L).
2. Radius of the blood vessel (r).
3. Viscosity of the blood (η).

Resistance is directly proportional to the length of the blood vessel.

$$\text{Resistance} \propto \text{Length}$$

$$\text{i.e.} \quad R \propto L$$

Resistance is inversely proportional to the fourth power of the radius of the blood vessel.

$$\text{Resistance} \propto \frac{1}{\text{Radius}}$$

$$\text{i.e.} \quad R \propto \frac{1}{r^4}$$

Resistance is directly proportional to the viscosity of blood.

$$\text{Resistance} \propto \text{Viscosity}$$

$$\text{i.e.} \quad R \propto \eta$$

Hence combining all three relationships to resistance:

$$R \propto \frac{L\eta}{r^4} \qquad \text{——————} (4)$$

Sustituting the value of R in equation (3):

$$F \propto \frac{P_A - P_B}{\frac{L\eta}{r^4}} \qquad \text{——————} (5)$$

$$F \propto (P_A - P_B) \times \frac{r^4}{L\eta}$$

$$F = k (P_A - P_B) \times \frac{r^4}{L\eta} \qquad \text{——————} (6)$$

$$k = \frac{\pi}{8}$$

Substituting the value of k in equation (6):

$$F = \frac{\pi}{8}(P_A - P_B) \times \frac{r^4}{L\eta} \quad \text{——————} (7)$$

Equation (7) is referred to as the Poiseuille Hagen Equation for blood flow. In the narrative, the Poiseuelle Hagen Equation reads as follows: Blood flow between two points in a blood vessel is directly proportional to the pressure difference between the two points, and to the fourth power of the radius of the blood vessel. Further the blood flow between the two points is inversely proportional to the length of the blood vessel and to the viscosity of blood.

In the circulatory system blood has to flow through branching tubes of the capillary beds. The total cross-sectional areas in the different parts of the circulatory system are as follows:

Aorta	= 20 sq cm.
Arteries	= 400 sq cm.
Arterioles	= 4500 sq cm.
Venules	= 4000 sq cm.
Veins	= 40 sq cm.
Vena Cavae	= 18 sq cm.

As the total cross sectional area increases, the velocity of blood flow decreases (refer Diagram VIII). Hence, the velocity of blood flow will be the least in the

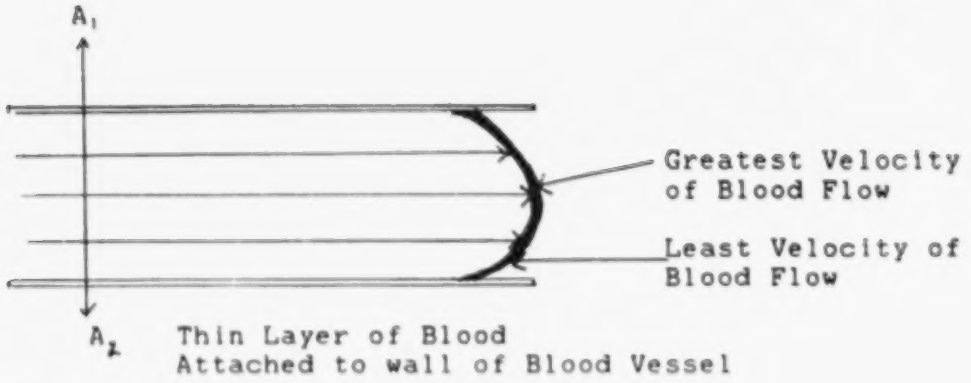
capillary beds where the cross sectional area is the greatest. This phenomenon is advantageous to the circulatory system in the human. In the capillary beds where the velocity of blood is the least, the blood is maintained for a longer time. This allows for diffusion of material from the blood to tissue fluid and also promotes diffusion in the opposite direction.

APPENDIX B

Accompanying Visuals for the Audiotape on Hemodynamics

Diagram I

Laminal Flow of Blood



Laminal Flow of Blood A_1-A_2

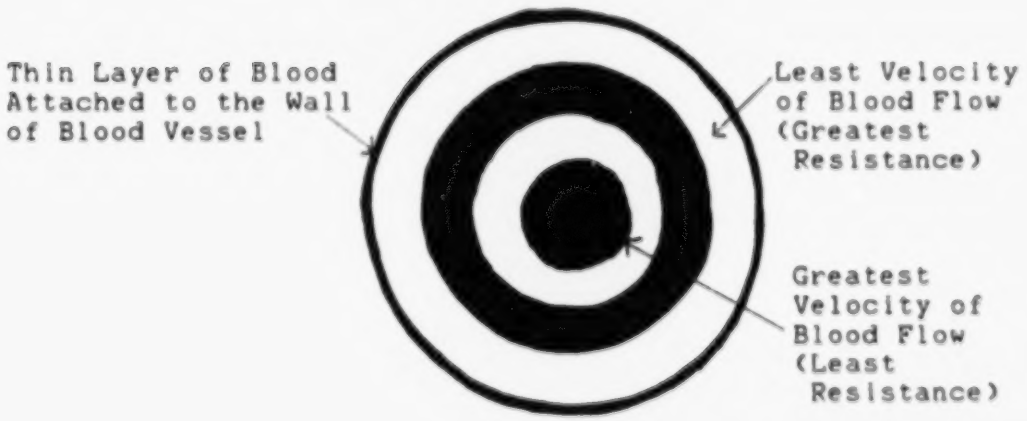
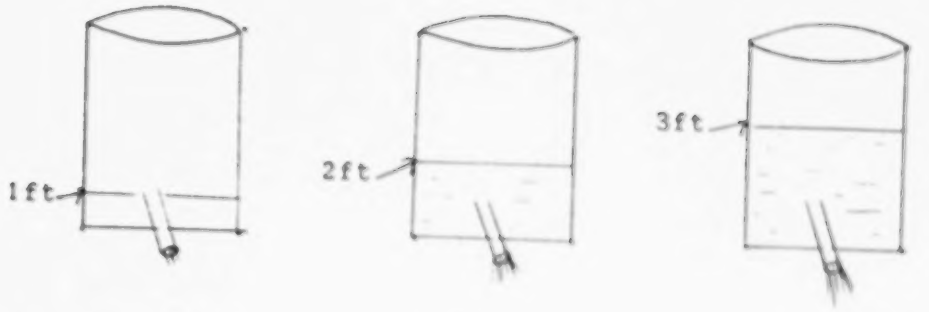

Thin Layer of Blood Attached to the Wall of Blood Vessel
Least Velocity of Blood Flow (Greatest Resistance)
Greatest Velocity of Blood Flow (Least Resistance)

Diagram II

Effect of Pressure on Flow



1 gal/min 2 gal/min 3 gal/min

Flow $\propto$ Pressure

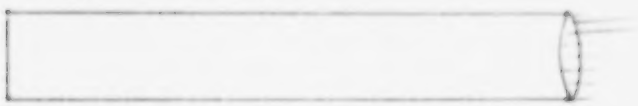
$F \propto P$

Diagram III

Effect of length of Vessel on Flow

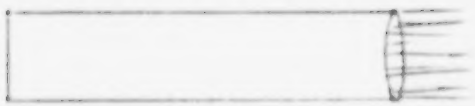
(Pressure Constant = 100 mm of Hg)

Length = 3 inches



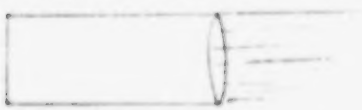
Flow = 1ml/min

Length = 2 inches



Flow = 2ml/min

Length = 1 inch



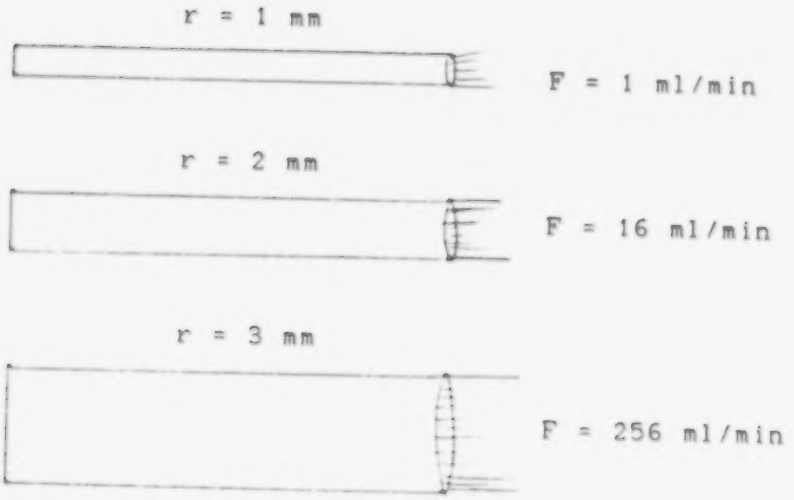
Flow = 3ml/min

$$\text{Flow} \propto \frac{1}{\text{Length of Vessel}}$$

$$F \propto \frac{1}{L}$$

Diagram IV

Effect of Radius of Vessel on Flow
(Pressure Constant-100 mm of Hg)

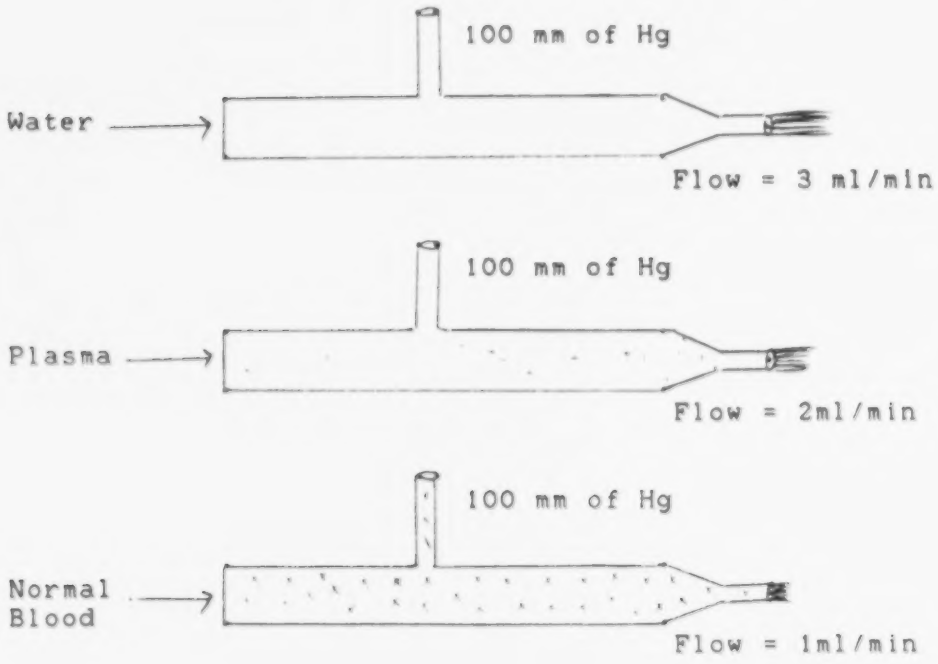


Flow $\propto$ Radius^4

$F \propto r^4$

Diagram V

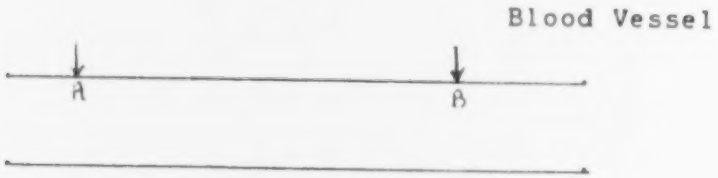
Effect of Viscosity on Flow
(Pressure Constant = 100 mm Hg)



$$\text{Flow} \propto \frac{1}{\text{Viscosity}}$$

$$F \propto \frac{1}{\eta}$$

Diagram VI
Flow in a Blood Vessel
(Pressure Constant = 100 mm of Hg)



P_A = Pressure at A

P_B = Pressure at B

Flow from A to B $\propto P_A - P_B$

$F \propto P_A - P_B$

Diagram VIII
(Hemodynamics - Poiseuille Hagen Equation)

$F \propto P_A - P_B$

$F \propto \frac{1}{R}$

$F \propto \frac{P_A - P_B}{R}$ _____ (1)

$R \propto L$

$R \propto \eta$

$R \propto \frac{1}{r^4}$

$R \propto \frac{L\eta}{r^4}$ _____ (2)

F = Blood Flow
$P_A - P_B$ = Pressure Difference between two points in a vessel
R = Resistance
L = Length
η = Viscosity of Blood
r = Radius of vessel

Substitute for R in equation (1)

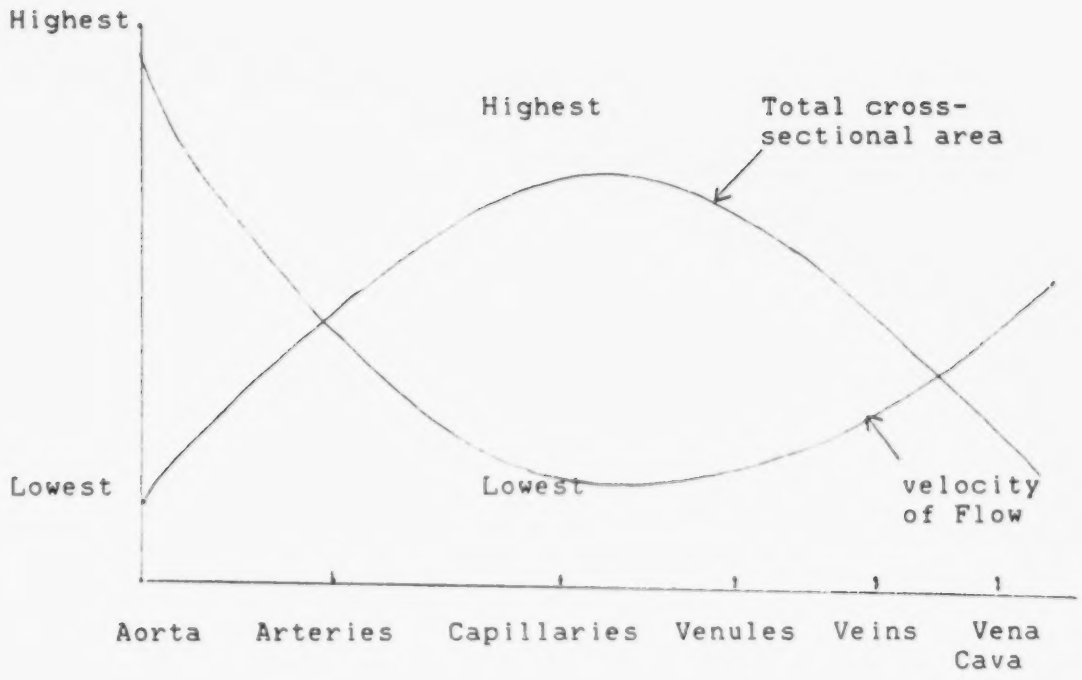
$F \propto \frac{P_A - P_B}{\frac{L\eta}{r^4}}$

$F \propto (P_A - P_B) \times \frac{r^4}{L\eta}$

$F \propto k\ (P_A - P_B) \times \frac{r^4}{L\eta}$ $\quad k = \frac{\pi}{8}$; $\pi = \frac{22}{7}$

The flow of blood from point A to point B in a vessel is directly proportional to the pressure difference between the two points and to the fourth power of the radius, and inversely proportional to the length of the vessel and to viscosity of blood. This is the Poiseuille Hagen Equation.

Diagram VIII
(Relationship of Cross Sectional Area to Flow of Blood)



Calculation of Mean and Standard Deviation
for Group I

Calculation of the Mean and Standard Deviation for Group I

Student No.	X_1	X_1^2
1	80	6400
2	62	3844
3	75	5625
4	49	2401
5	95	9025
6	72	5184
7	77	5929
8	58	3364
9	79	6241
10	82	6724
11	75	5625
12	79	6241
13	68	4624
14	81	6561
15	80	6400
16	75	5625
17	69	4761
18	67	4489
19	76	5776
20	81	6561
$n = 20$	$\Sigma X_1 = 1480$	$\Sigma X_1^2 = 111400$

$$\bar{X}_1 = 74$$

$$\sigma = \sqrt{\frac{n\,(\Sigma X_1^2) - (\Sigma X_1)^2}{n^2}}$$

$$= \sqrt{\frac{20\,(111400) - (1480)^2}{20 \times 20}}$$

$$= 9.695$$

Calculation of Mean and Standard Deviation
for Group II

Calculation of Mean and Standard Deviation for Group II

Student No.	X_2	X_2^2
1	85	7225
2	65	4225
3	77	5929
4	52	2704
5	97	9409
6	78	6084
7	78	6084
8	65	4225
9	82	6724
10	85	7225
11	80	6400
12	79	6241
13	70	4900
14	79	6241
15	83	6889
16	77	5929
17	74	5476
18	68	4624
19	78	6084
20	91	8281
n = 20	$\Sigma X_2 = 1543$	$\Sigma X_2^2 = 120899$

$\bar{X}_2 = 77.15$

$$\sigma = \sqrt{\frac{n(\Sigma X_2^2) - (\Sigma X_2)^2}{n^2}}$$

$$= \sqrt{\frac{20(120899) - (1543)^2}{20 \times 20}}$$

$$= 9.634$$

Calculation of t Value

Calculation of the t Value

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1^2} + \frac{s_2^2}{n_2^2}}}$$

$$t = \frac{77.15 - 74.00}{\sqrt{\frac{9.634^2}{20^2} \quad \frac{9.695^2}{20^2}}}$$

$$t = \frac{3.15}{\sqrt{\frac{92.81}{400} + \frac{93.99}{400}}}$$

$$t = \frac{3.15}{\sqrt{0.234 + 0.235}}$$

$$t = \frac{3.15}{\sqrt{0.469}}$$

$$t = \frac{3.15}{\sqrt{0.685}}$$

$$t = 4.59$$